Jordan Cove Urban Watershed National Monitoring Project

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Introduction

Stormwater runoff from urban and urbanizing areas is widely recognized as a major cause of water pollution in the United States. The impacts of stormwater runoff are threefold: (1) chemically, contaminants deposited on the land are carried by runoff and infiltration to surface and groundwater; (2) physically, increases in impervious surfaces raise runoff rates which, in turn, increase mass pollutant loadings and contribute to erosion and sedimentation; and (3) biologically, the combined chemical and physical alterations of watershed systems degrade aquatic habitat. Research over the past 20 years consistently shows a strong correlation between the imperviousness of a drainage basin and the health of its receiving waters, with stream health decreasing with increasing impervious coverage of the watershed.[1] The U.S. Environmental Protection Agency cites urban runoff as the second leading cause of impairment to estuaries and the fourth leading cause of impairment to lakes.[2] Increased runoff rates, and the erosion and sedimentation associated with new development and construction, also are significant sources of pollution. In the United States, there are an estimated 522,000 construction "starts" each year, with construction activities disturbing an estimated 5 million acres of land annually.[3]

Connecticut communities, like those in many urbanized states, are confronted with meeting nonpoint source management needs that often conflict with traditional subdivision regulations and construction standards. The challenge of meeting publicsafetyand maintenance requirements in an environmentally sensitive manner is not currently being met, as evidenced by continued water quality impairments associated with new development. Can impervious surfaces be reduced, and curbing and storm drains be eliminated in a way that will not raise objections from municipal boards and commissions? Will homeowners accept cluster housing, natural landscaping, and "greener" home and yard maintenance practices? Most important, will those modifications make a difference in the quality and quantity of nonpoint source runoff under widespread application? Answering these and related questions is the objective of the Jordan Cove Urban Watershed National Monitoring Project.

Project Overview

The primary purpose of the Jordan Cove project is to compare differences in runoff quantity and quality emanating from traditional and "environmentally sensitive" development sites. The 18-acre "Glen Brook Green" subdivision, located in the southeastern Connecticut town of Waterford, is being constructed and monitored to make this comparison. The subdivision is split into two distinct "neighborhoods": one with building lots arranged in a traditional R-20 (half-acre) zoning pattern (Figure 1); the other, cluster housing with a variety of best management practices (BMPs) incorporated into the design (Figure 2).

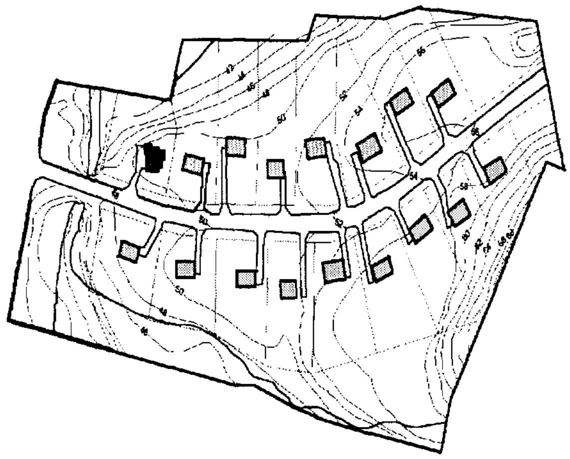

Figure 1. Glen Brook Green "Traditional" Neighborhood.

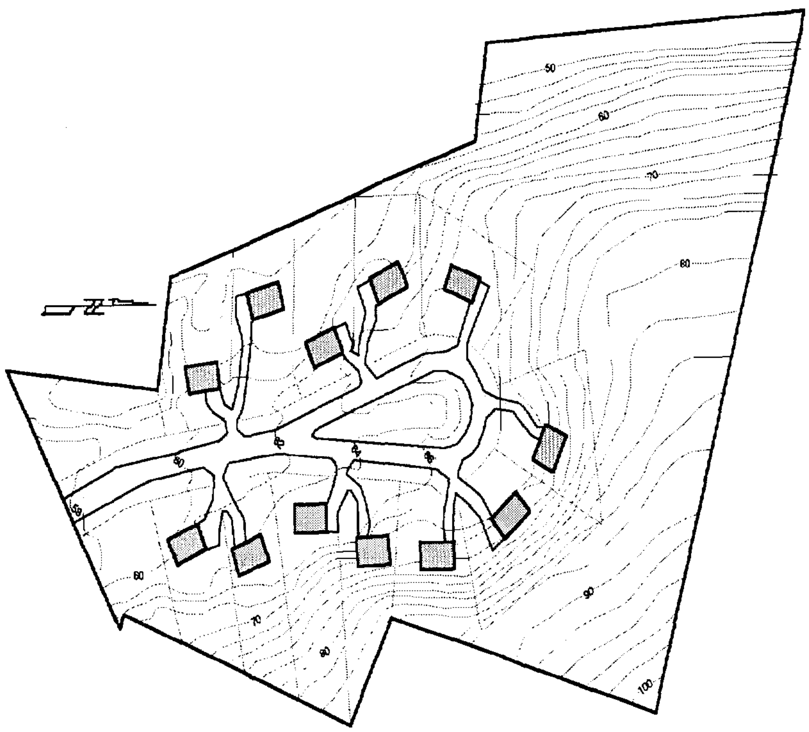

Figure 2. Glen Brook Green "BMP" Neighborhood.

Stormwater runoff from the traditional section is collected by curbs and catch basins, then piped through astormwater treatment system before entering Nevins Brook, a tributary of Jordan Brook and, ultimately, Jordan Cove and Long Island Sound. Homeowners will not be subjected to any enhanced environmental education, or restrictions on how they manage their properties.

The BMP neighborhood will feature grass swales; roof leader "rain gardens;" shared, permeable driveways; small building "foot-prints;"deed restrictions on increasing impervious surfaces; "low-mow," "no-mow," and conservationzones; a narrower, permeable road surface (interlocking concrete pavement); and a vegetated infiltration basin, or bioretention area, located inside a "tear-drop" *cul* de sac. Several different driveway surfaces will be utilized, including interlocking concrete pavement, gravel, concrete tire strips, and permeable asphalt, and monitored for their relative runoff rates. Homeowners and town road maintenance crews will be encouraged to adopt pollution prevention techniques, including controlled fertilizer and pesticide application, pet waste management, street sweeping/vacuuming, and reduced use of deicing agents.

The BMP neighborhood is expected to generate less stormwater runoff and pollution. Monitoring conducted before, during and after construction will document actual results. The Jordan Cove project team comprises a true public/private partnership, with researchers and educators from the University of Connecticut; federal, state, and local government officials; private consulting firms; and the developer.

National Monitoring Program

The Jordan Cove Urban Watershed National Monitoring Project is funded, in part, through the Connecticut Department of Environmental Protection (CT DEP) by the U.S. Environmental Protection Agency's (EPA) Section 319 National Monitoring Program (NMP). It is one of 22 such projects nationwide. The Jordan Cove project is the only NMP project studying the effects of residential subdivision development on runoff quality and quantity, and of BMPs designed to mitigate those impacts.

The Section 319 NMP was established pursuant to section 319(l) of the federal Clean Water Act (Nonpoint Source Management Programs - Collection of Information). Section 319(l) states that EPA shall collect information and make available:

(1) Information concerning the costs and relative efficiencies of best management practices for reducing nonpoint source pollution.

(2) Data concerning the relationship between water quality and implementation of various management practices to control nonpoint sources of pollution.

The objectives of the Section 319 NMP are twofold:

(1) To scientifically evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution.

(2) To improve our understanding of nonpoint source pollution.

To achieve these objectives, the NMP has selected watersheds across the country to be monitored over a 6-to 10-year period to evaluate how improved land management and the application of BMPs reduce water pollution. The results from these projects will be used to assist land use and natural resource managers by providing information on the relative effectiveness of BMPs to control nonpoint source pollution.

Site Selection

In 1993, nonpoint source program staff from EPA and CT DEP, and a University of Connecticut researcher began efforts to identify a site at which to conduct a nonpoint source monitoring project under the auspices of the NMP. Initial site selection involved three criteria: (1) an appropriate hydrologic setting, with distinct drainage patterns amenable to monitoring; (2) a willing land owner or developer who would allow l-1 ½ years of advance monitoring before beginning construction; and (3) a municipality willing to adopt innovative site planning and development strategies. Proximity to the coast was also considered as an important factor because of the need to reduce nonpoint source pollution loads to Long Island Sound and coastal waters in general.

CT DEP mailed letters soliciting interest to a number of municipalities recognized for either their progressive approach to land use planning and management, orforexperiencing high development rates. After positive responses from several municipalities, and numerous field visits, the "Glen Brook Green" site in Waterford was selected in May 1995. The 18-acre parcel was an active chicken farm, but its owner, who had grown up on the farm, was planning to develop it into a residential subdivision. The property owner wanted to develop the parcel in an environmentally-sound manner, was interested in the NMP solicitation, and was willing to be flexible with his construction schedule to facilitate monitoring.

The hydrology of the parcel featured two distinct drainage areas, an ideal setting for the proposed monitoring design. Poultry houses and several other buildings occupied the area that would become the traditional neighborhood and an old, partially mined gravel pit dominated the future BMP neighborhood. Soil tests determined that the chicken manure had not elevated nutrient levels significantly enough to bias the monitoring. The town of Waterford, and its planning officials, had a reputation as being progressive on land use issues and had served as one of the pilot communities for the University of Connecticut Cooperative Extension System's Nonpoint Education for Municipal Officials (NEMO) project. Because waivers from Water-ford's subdivision regulations would be needed to build the BMP neighborhood, the town's cooperation was critical to the project's implementation.

Planning

Proceeding from a conceptual design to actual construction required a concentrated effort by the project team working together toward a common goal. Once an acceptable plan was agreed upon by the project team and committed to paper, the next step was gaining approval from Water-ford's conservation, and planning and zoning commissions. As is typical of New England town governments, both commissions paid close attention to planning decisions at a series of public meetings at which many development alternatives were reviewed. Volunteer commissioners and professional staff raised numerous concerns regarding the health, safety and general welfare of the town residents, and the social economic, environmental, and political viability of the proposed plan. Among their concerns were road widths for emergency access, road surface integrity for plowing and de-icing, traffic, drainage, sidewalks, parking, maintenance of common areas, and responsibility should BMPs fail. The rigorous review was enlightening to the project team and commissioners alike. As the ongoing dialogue between the various parties led to further planning details and innovative solutions to problems, enthusiasm and support for the project grew.

After a series of public meetings in late 1996 and early 1997, the project was approved by both commissions. Technical modifications of existing standards were handled in four ways: as waivers, special design/operation controls, mitigation, or discretionary actions. Table 1 lists each of these categories with associated comments and concerns expressed by Water-ford's professional staff and commissions. In the end, it was the willingness of all parties involved to work in concert, reaching compromises, that allowed this innovative project to advance to the construction phase.

It is a generally accepted axiom that resource-based site planning can help minimize increases in runoff and reduce the potential for erosion and sedimentation problems typically associated with new development. In this project, goals identified at the outset are helping to direct the choice of practices and strategies for site development toward those that will reduce adverse impacts on hydrology and water quality. These goals include: (1) reproducing pre-development hydrological conditions; (2) confining development and construction activities to the least critical areas; (3) fitting the development to the terrain; (4) preserving and utilizing the natural drainage system; and (5) creating a desirable living environment.

Table 1. Technical Modifications of Existing Development Standards.

Considerations	Traditional Design	BMP/Cluster Design	Comments
waivers needed	specified road surface materials	segmental concrete pavers (permeable)	must be approved by public works; costs more
	typical road width = 28 feet, reduced to 24 feet	reduced road width to 20 feet for travel lane	must be approved by public works, fire, and police
	curbs and storm drains required	no curbs; grassed swales and sheet flow off road	turf stone installed to maintain road edge integrity; costs less
	90 ft paved cul-de-sac radius	one way cul de sac design to reduce road width and turning radius	further reduction in width and less need for snow plowing
special design/ operational control	planning and zoning standards	bioretention "rain gardens"	retains roof runoff on-site
	home owner discretion	vegetative maintenance	reduces fertilizer use; costs less
	home owner discretion	pesticide management	reduces pesticide use: costs less
	home owner discretion	domestic animal management	reduces pathogen runoff
mitigation required	road runoff piped to storm sewer		need to manage storm water entering the site from adjacent public road
	creation of 13,400 sq ft wetland at subdivision entrance		required to mitigate filling of 5000 sq ft of wetlands within subdivision
discretionary actions	R-20 single-family zoning	cluster and zero setback from lot lines	allows more open space and natural landscaping
	open space not contiguous with all lots	open space layout	compact housing; natural landscaping
	a driveway for each home	combined driveways	reduces curb cuts and impervious surface; cost less

Monitoring Design

This study is utilizing the "paired-watershed" monitoring design, which requires a minimum of two watersheds (control and treatment) and two periods of study (calibration and treatment). This approach assumes that there is a quantifiable relationship between paired water quality data for the two watersheds, and that this relationship is valid until a major change is made in one of the watersheds. It does not require that the quality and quantity of runoff be statistically the same for the two watersheds, but that the relationship between the paired observations of water quality and quantity remains the same over time -- except for the influence of the land use changes in the treatment watershed.[4]

The control watershed accounts for annual and/or seasonal climate variations. During the calibration period, no changes in land use occur in the watersheds and paired water quality and quantity data are collected to develop a baseline. The paired data are used to develop regressions for the control and treatment watersheds. The treatment period begins when changes in land use occur in the treatment watershed. A new regression is developed following the treatment period. Analysis of variance (ANOVA) is used to test the significance of the regressions in each period. Analysis of covariance (ANCOVA) is used to test the differences between the two regression slopes and intercepts. The changes between periods are calculated based on a comparison of predicted values, using the calibration regression equation, and observed values during the treatment period.[5]

For the Jordan Cove project, the treatment period will occur in two phases: (1) during construction of the traditional and BMP neighborhoods; and (2) after construction when the BMPs are in effect. The paired-watershed approach is being used to measure the differences in water quality and quantity between the treatment areas (traditional and BMP neighborhoods) and the control area (a nearby 1 O-year old subdivision) caused by construction in the two treatment areas and the application of BMPs in the BMP neighborhood. Stormwater quality and quantity are measured at the outlets of each of the two treatment neighborhoods, and the control watershed (Figure 3). Water quality is measured by analyzing weekly flow-weighted composite samples for total suspended solids (TSS), total phosphorus (TP), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH,-N), and nitrate+nitrite nitrogen (NO,-N). Grab samples are analyzed for fecal coliform and BOD,. Monthly analyses are conducted for copper, lead, and zinc.

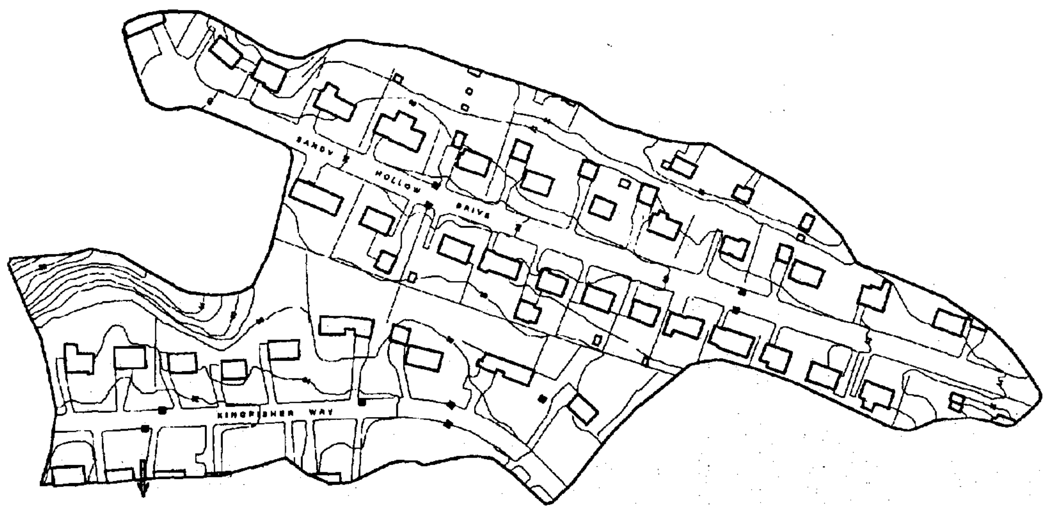

Figure 3. Existing residential (control) watershed.

The calibration period began in January 1996, to establish a baseline for future comparisons. Since the treatment period began in May 1998, runoff monitoring has focused on the effects of construction, and on the relative effectiveness of standard erosion and sediment control practices in the traditional neighborhood. When construction commences in the BMP neighborhood, the focus will be on the effects of construction and the relative effectiveness of enhanced erosion and sediment control practices (e.g., phased grading, stockpile seeding, open space vegetation, cross grading, and detention swales). Post-construction monitoring is scheduled to begin in 2001 and will continue for 3-5 years.

Supplemental monitoring will be conducted on selected BMPs, including different driveway surfaces and enhanced turf management in the BMP neighborhood, and a “state-of-the-art” stormwater treatment device in the traditional neighborhood. This information will be used to evaluate the effectiveness of these specific practices.

Monitoring Results

During the calibration period, 75 runoff events were sampled for the control watershed and 12 runoff events for the two treatment watersheds. In the treatment period to date, 21 and 20 events were sampled for each treatment watershed, respectively. Peak discharge values were obtained for nine paired events in the calibration period and 20 pairs for the treatment period. The total number of samples analyzed was less than the total number of flow observations because not all the samples contained a sufficient volume for analysis[6].

Sampling results to date, as presented in Table 2, indicate that construction of the traditional neighborhood is causing significant impacts on runoff quality and quantity, including observed increases in mean weekly flow volume (99%), runoff frequency (from 16% to 95%), and mean weekly peak discharge (79%).[7] The conversion of the watershed's topography from a "knoll" to a "bowl," combined with an increase in impervious surface, appears to have caused a significant change in hydrologic responses. Concentrations of NO,-N and Pb in runoff also increased. However, increases in the concentrations of sediment and sediment-associated nutrients, typical of construction sites, did not occur. In fact, TKN concentrations have declined during construction. It is believed that erosion and sediment controls are responsible for TSS concentrations remaining constant before and during construction*.

Table 2. Summary of means and percent increases of flow, Q_p, nutrient and metal concentrations for the control and traditional watershed in the calibration and treatment periods.

Calibration Period			Treatment Period			
				Traditional		
Parameter	Control	Traditional	Control	Observed	Predicted	% Change
---(m³/week)---						
Flow	113.84	0.14	107.76	1.94	0.02	99***
---(m^3/sec*week)---						
Qp	0.05	3.00E-04	0.04	1.00E-03	3.00E-04	79***
---(mg/L)---						
TSS	31	132	28	106	121	-15
NO_3-N	0.5	0.3	0.4	0.8	0.3	62**
NH_3	0.15	0.08	0.31	0.18	0.17	2
TKN	1.3	4.0	1.8	2.1	4.5	-113**
TP	0.159	1.009	0.127	0.481	0.758	-58
---(ug/L)---						
Cu	8	8	14	21	13	38
Pb	6	11	6	17	10	42*
Zn	58	65	79	126	98	22

* **P value < 0.05**
** P value < 0.01
. ** P value < 0.001

Coinciding with the increases in pollutant concentration and flow, the mass export of NO,-N and Pb increased as well, as did the mass exports of TP, TSS, Cu, and Zn. These increases appear to be attributable to increased stormwater runoff volumes. The preliminary results from this study suggest that increased runoff, rather than erosion, is the cause of increased pollutant export from this construction site. Traditionally, erosion and sediment controls and stormwater management plans focus on the prevention of sediment and, occasionally, peak flow impacts on downstream areas. The preservation of pre-development hydrologic conditions within the watershed where construction is occurring is typically ignored.

Excess runoff, which is the driving force behind nonpoint source pollution, will transport pollutants into waterways and contribute to their degradation. Preliminary monitoring results demonstrate that erosion and sediment controls can reduce sediment and sediment-associated pollutants in construction site runoff. However, current erosion and sediment control practices do not address the increase in runoff from development sites. Consequently, these practices fail at reducing pollutant loads.[9]

Next Steps

By the end of 2000, this combination of traditional and "green" designs for residential subdivisions should be fully constructed. Monitoring of stormwater quality and quantity will be conducted for several years after build-out to determine the overall efficiency of the design. It should demonstrate that careful planning, landscaping, and use of vegetative BMPs can help protect and enhance the environment, while addressing other concerns that local planning and zoning commissions face. Lessons learned from this project have already been, and will continue to be, passed along to other communities through ongoing technical assistance and training programs administered by the CT DEP, the University of Connecticut Cooperative Extension System, and other agencies and organizations.

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